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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,393,880**, on July 17, 2002, by **TACTEX CONTROLS INC.**, assignee of David M. Lokhorst and Robert D. Inkster, for "Bed Occupant Monitoring System".

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August 22, 2003
Date

Canada

(CIPO 68)
04-09-02

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ABSTRACT

This invention relates to monitoring the health and/or activity of a person occupying a bed. This invention provides a novel system comprising a pressure-sensitive surface and interface electronics.

Systems made in accordance with the present invention may be used for a variety of applications including but not limited to any of the following (or combination of the following): detecting the presence or absence of a bed occupant; determining if the bed occupant is preparing to exit the bed; measuring pulmonary activity (eg. respiration rate); monitoring the frequency and extent of movement of the bed occupant; monitoring the heart beat of the occupant; monitoring the bed occupant's blood pressure; monitoring the pressure at the interface between the bed occupant and the bed. Furthermore, it will be understood from the following description that the present invention provides a non-intrusive means of monitoring the bed occupant. The invention comprises a pressure sensitive surface that may be soft and conformable upon which the occupant lies. If desired, the pressure sensitive surface can be fabricated in a manner such that the bed occupant is unaware of its presence.

Given these features, it is evident that the present invention provides: a useful tool in long term care facilities wherein it is sometimes desirable to determine whether a bed occupant intends to leave the bed; a means to detect the possible onset of bed-sores in time for an attendant to prevent such sores from occurring by moving the bed occupant; a means to detect the lapse of regular pulmonary activity (to help prevent sudden infant death syndrome or death of a bed-ridden patient).

BED OCCUPANT MONITORING SYSTEM

Overview

This invention relates to monitoring the health and/or activity of a person occupying a bed. This invention provides a novel system comprising a pressure-sensitive surface and interface electronics.

Systems made in accordance with the present invention may be used for a variety of applications including but not limited to any of the following (or combination of the following): detecting the presence or absence of a bed occupant; determining if the bed occupant is preparing to exit the bed; measuring pulmonary activity (eg. respiration rate); monitoring the frequency and extent of movement of the bed occupant; monitoring the heart beat of the occupant; monitoring the bed occupant's blood pressure; monitoring the pressure at the interface between the bed occupant and the bed. Furthermore, it will be understood from the following description that the present invention provides a non-intrusive means of monitoring the bed occupant. The invention comprises a pressure sensitive surface that may be soft and conformable upon which the occupant lies. If desired, the pressure sensitive surface can be fabricated in a manner such that the bed occupant is unaware of its presence.

Given these features, it is evident that the present invention provides: a useful tool in long term care facilities wherein it is sometimes desirable to determine whether a bed occupant intends to leave the bed; a means to detect the possible onset of bed-sores in time for an attendant to prevent such sores from occurring by moving the bed occupant; a means to detect the lapse of regular pulmonary activity (to help prevent sudden infant death syndrome or death of a bed-ridden patient).

Description

Throughout the following description, specific details are set forth in order to provide a more thorough understanding. However, the invention may be practised without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the present invention. According, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

The present invention is illustrated schematically in Figure 1. A bed occupant 6 lies upon a support surface 4. The present invention comprises a pressure sensitive surface 1 and interface electronics 2. The interface electronics 2 may be housed in a single enclosure as illustrated, or they may be housed in more than one enclosure connected by signal means (not shown). Optionally, it may also comprise an indicator device 3. Such an indicator may be an visible or audible alarm, a data display system, an attendant call system, or a data logging system.

It must be understood that Figure 1 is a schematic representation and therefore does

not accurately illustrate the physical locations and sizes of the elements. For example, among other things, the pressure sensitive surface 1 may be a pad location in-between the occupant 6 and the support surface 4, or it may be embedded in the support surface itself as will be described subsequently.

The pressure sensing surface 1 comprises a plurality of individual pressure sensors 5. Although infinitely many arrangements of sensors are possible, the pressure sensors are preferably arranged in a rectangular array 2 cm to 10 cm apart, extending across the width of the support surface 4. Depending on the intended application, the array of pressure sensors may extend the entire length of the support surface 4 or some portion of the length. For example, to monitor the bed occupant's respiration, the inventors have found that a 60-sensor array approximately 90cm wide by 30cm in length is sufficient. A larger device with correspondingly more sensors may be used.

The pressure sensors 5 measure the bearing pressure applied by the occupant in the proximity of the pressure sensor. A change in the bearing pressure results in a change in the output of the pressure sensor 5. The pressure sensors 5 are preferably responsive to pressures in the range of 1 to 15 mm Hg.

It is preferred that the pressure sensors 5 are pressure sensors made in accordance with US Patent 5,917,180, Reimer et al., referred to herein as "Kinotex pressure sensors." Refer to that document for a description of how Kinotex pressure sensors function (details of which are omitted here for brevity).

Figures 2 and 3 illustrate a pressure sensitive surface 1 in accordance with the present invention. The pressure sensitive surface 1 comprises a plurality of Kinotex pressure sensors 5 that are sandwiched between two layers of soft polyurethane foam. Several bundles of plastic optical fibres 8 deliver and retrieve the light energy from the Kinotex pressure sensors. In the proximity of each Kinotex pressure sensor, an area of adhesive 11 is used to secure the plastic optical fibres to the foam above and below. The bundles of fibre 8 each comprise a number of fibre pairs 14,15. A pair of fibres 14,15 is terminated at each sensor location. The fibres bundles 8 are not adhered along their length so as to provide some flexibility and resilience to the entire assembly. The top foam layer 9 and the bottom foam layer 11 are material for chosen to be suitable for Kinotex pressure sensors. The inventors have determined that white or natural-coloured low density polyurethane foam are suitable material for this purpose. Such foam is available from, among others, Lendell Manufacturing Inc. of St. Charles, Michigan, product code HSS. The inventors have also determined that most standard bed mattress foam materials are satisfy the requirements of this invention. It will be understood that many different foam materials provide similar characteristics and the present invention is not limited to a specific material. An opaque covering material (not shown) is required to keep ambient light from disturbing the Kinotex pressure sensors. The bundles of optical fibre 8 are gathered and optionally passed through a protective sleeve 12 that terminates at the interface electronics 2.

A pressure sensitive pad made as described above is flexible and soft. Such a pressure

sensitive pad can be placed on a support surface (i.e. bed mattress), underneath the sheets and coverings upon which the occupant lies. The inventors have determined that the invention practised in this manner is essentially undetectable to the bed occupant being monitored.

The present invention may be practised by locating the pressure sensors 5 in a number of different locations. Figure 4 illustrates some embodiments of the invention. Figure 4(a) illustrates an embodiment wherein a pressure sensitive surface is made by placing or adhering a pad, made as described above, on top of a bed mattress. Figure 4(b) illustrates and embodiment wherein the pressure sensors have been embedded into a bed mattress so as to be coplanar with the top surface. Figure 4(c) illustrates an embodiment wherein the mattress is made of at least two layers laminated together, between which are sandwiched the pressure sensors. Figure 4(d) illustrates an embodiment wherein the pressure sensitive surface is made by embedding pressure sensors in the bottom surface of the mattress so that the bottom is coplanar with the bottom of the mattress. Figure 4(e) illustrates and embodiment wherein a pressure sensitive surface is made by placing or adhering a pad, made as described above, below the mattress. In all these cases, the Kinotex pressure sensors may optionally utilize the foam of the mattress itself as the optical medium.

As described in Reimer et al., Kinotex pressure sensors utilize and optical-to-electronic interface. The optical-to-electronic interface comprises one or more light transmitters (such as a light-emitting-diode) and one or more photo-detectors (such as a photodiode or photo-transistor). The interface electronics 2 comprise these opto-electronic components as well as some signal conditioning.

In one embodiment of this invention, the optical-to-electronic interface comprise at least one LED and one photo-sensor, and the signal conditioning electronics comprise analogue circuit elements configured to provide an output signal representative of the total pressure applied to the pressure sensitive surface. In another embodiment of the present invention, the optical-to-electronic interface comprises at least one LED and more than one photo-sensor, and the signal conditioning electronics comprise analogue circuit elements configured so as provide pone or more output signals representative of the pressures applied to different regions of the pressure sending surface. In another embodiment of this invention, the signal conditioning circuitry includes measurement of all of the pressure sensors individually. In these embodiments, it would be most practical to use further circuitry to monitor the output signal or signals, and compare those output signals against pre-set thresholds. The thresholds may be set, for example, to indicate the presence or absence of an occupant in the bed. Alternatively (or additionally) further circuit elements may be included to extract other information from the signals, such as the time-derivative (i.e. time rate of change) of the signal or a high-pass filter or a low-pass filter or a notch filter or any combination of the foregoing. Each of these provides valuable information regarding the condition of the bed occupant. Design of the analogue circuitry necessary for the above embodiments is well known in the art.

As an example, a bed occupant sensor can be made in accordance with this invention.

The layout of pressure sensors in such a device is illustrated in FIGURE 5. A pressure sensitive pad 20 has a plurality of pressure sensors 5. The pressure sensors are divided into three groups 21, 22, and 23. A single LED (not shown) is used to illuminate all of the Kinotex pressure sensors. The responses of the pressure sensors within the central group 22 are summed by using a single photo-sensor (not shown) to detect their light output simultaneously. Pressure applied to any Kinotex pressure senor within the central group 22 will result in a change in the output signal from the optical-to-electronic interface. In a similar manner, the signals from the Kinotex pressure sensors in the side groups 21 and 23 are summed using a second photo-sensor (not shown). This results in two electronic signals: one representing the total pressure applied within the central region 22, and another representing the pressure applied within the region 23. Further analogue electronic is implemented to compare these signal and produce a third signal that is derived from these. The third signal indicates three possible states: 1) there is no occupant in the bed (determined by both first and second signals being below a threshold); 2) the bed occupant is in the central region (determined by the first signal being above a first threshold and the second signal being below a second threshold); 3) the bed occupant is near the edge of the bed (determined by the second signal being above the second threshold). The third signal can then be used to active an audible alarm or an attendant call system.

Although it is possible in principle to implement the invention using entirely analog electronics, it is preferable to use a combination of analogue and digital electronics. To explain this point, an example embodiment will be described. In this example, a pressure sensitive surface 1 is made as illustrated in FIGURES 2 and 3. The interface electronics are well known in the art and are described in documents available from Tactex Controls Inc., of Victoria, Canada. A simplified schematic illustration of the interface electronics 2 is given in FIGURE 6. A microprocessor 32 actives two LED drive circuits 31 that provide current to two LEDs 30. The LEDs 30 provide illumination for the pressure sensors 5. Each Kinotex pressure sensor has a pair of plastic optical fibres 14, 15. The light-receiving fibre 14 returns light to an array of photo-diodes 33, with each receiving fibre 14 being in a known alignment with a specific photo-diode. The microporcessor 32 provides control signals 38 that cause the array of photo-diode array output an analogue signal 39 corresponding to the light intensities from each of the pressure sensors 5. Optionally, the signal may be amplified, filtered, or otherwise conditioned by analogue circuitry 34. The signal is then converted to digital form by the analogue-to-digital-converter 35, and then read by the micro-processor 32. The microprocessor implements the necessary signal processing (described subsequently) and provides output signals 40 via appropriate driver circuitry 36. The driver circuitry may comprise well known electronic interfaces such as RS-232, RS-485, Ethernet, Universal Serial Bus, or others too numerous to list.

Several indications of health of the bed occupant may be monitored. In one embodiment, the inventive system is used to monitor pulmonary and/or heart activity of the bed occupant. Given the interface electronics of FIGURE 6, any or all of the following parameters may be computed by software implemented on the microprocessor: the time derivative of the sum of all pressure signals; the time

derivative of the sum of the squared pressure signals; or preferably, the time derivative of the sum of the absolute value of the pressure signals. The inventors have found that the pulmonary activity, heart activity, and bodily movement of the bed occupant can be observed from these computed parameters. FIGURE 7 is a typical graph of the sum of the derivative of the absolute value of pressure signal plotted against time. In the graph 50, time is indicated from left to right, along axis 51. The peaks 53 and 54 correspond to inhaling and exhaling respectively. The smaller more frequent peaks 55 correspond to heat beats. The large disturbance 56 corresponds to bodily movement (for example, when the bed occupant shifts his weight).

It will be evident to those skilled in the art that further signal processing can be invoked to measure the precise rate of respiration and/or the rate of heart beat from the signal shown in FIGURE 7.

In another embodiment, a threshold 57 may be set such that if the signal remains below the threshold 57 for an extended period of time, it indicates the suspension of pulmonary activity. Optionally, another threshold 58 can be set to indicate whether or not the bed occupant has moved.

In light of this disclosure, it is evident that many embodiments of the present invention may be implemented.

We claim:

1. A bed occupant monitoring system comprising:
   a) a plurality of Kinotex pressure sensors, and
   b) interface electronics that convert the optical signal from the Kinotex pressure sensors into electrical signals.

2. The system of claim 1 further comprising signal processing means used to determine whether the bed occupant is in the centre of the bed, near the edge of the bed, or entirely out of the bed.

3. The system of claim 1 further comprising signal processing means used to determine whether the bed occupant is moving or has moved within a set period of time.

4. The system of claim 1 further comprising signal processing means used to determine the respiratory rate of the bed occupant.

5. The system of claim 1 further comprising signal processing means used to determine the heart rate of the bed occupant.

6. The system of claim 1 further comprising signal processing means used to determine the bed occupant's blood pressure.

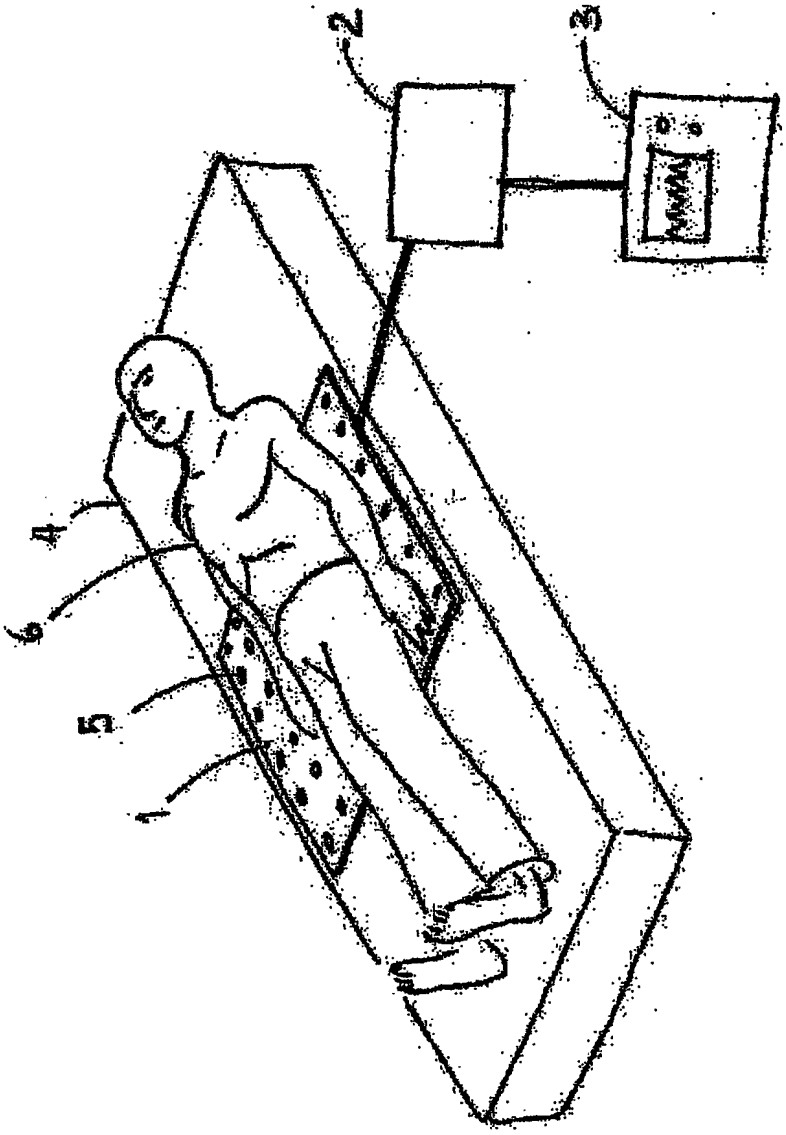

FIGURE 1

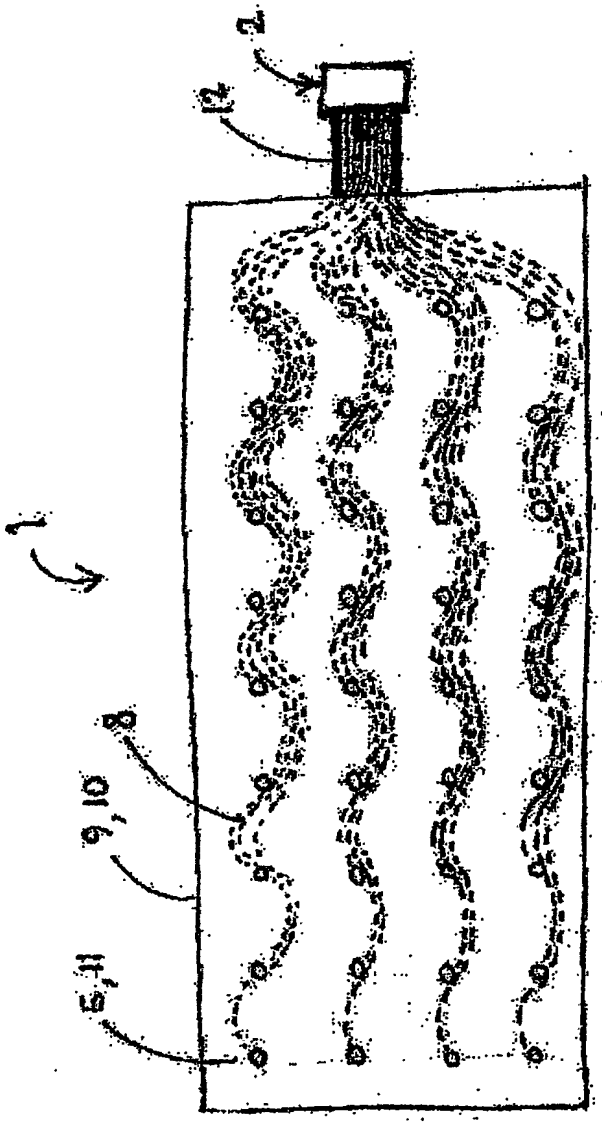

FIGURE 2

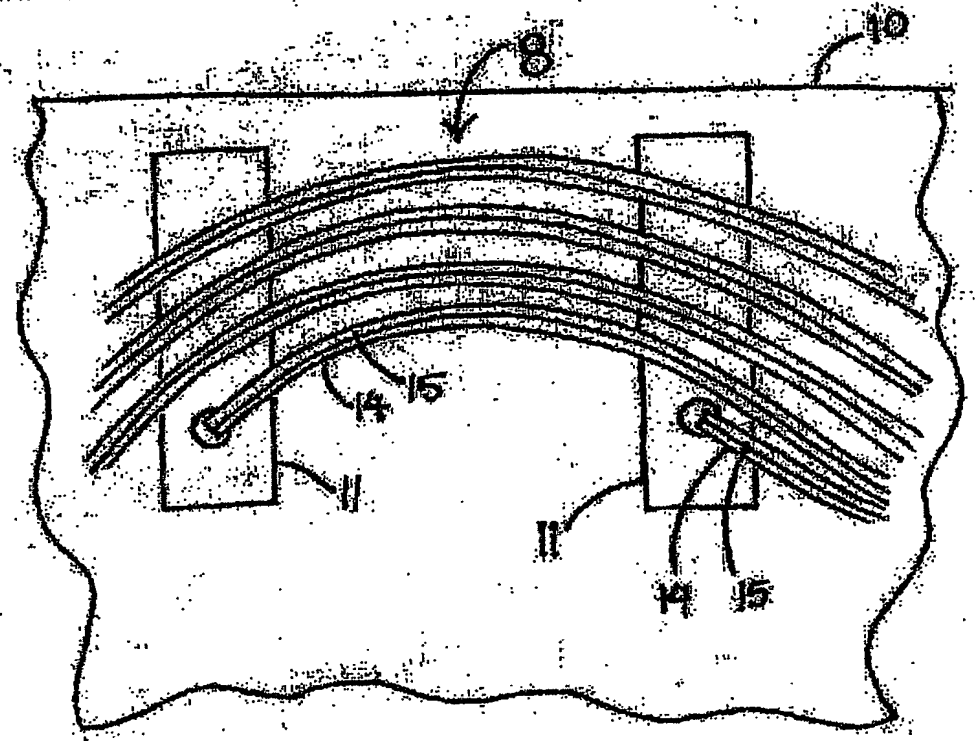

FIGURE 3(a) (TOP VIEW)

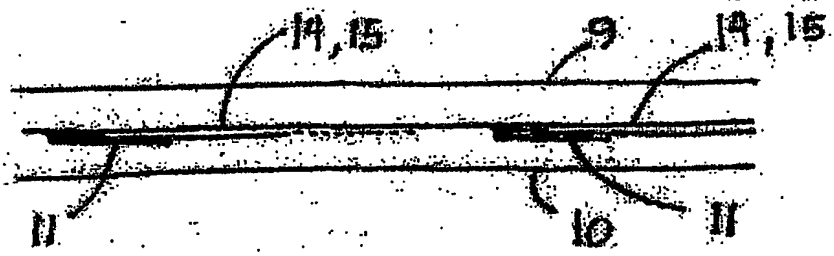

FIGURE 3(b) (CROSS-SECTION VIEW)

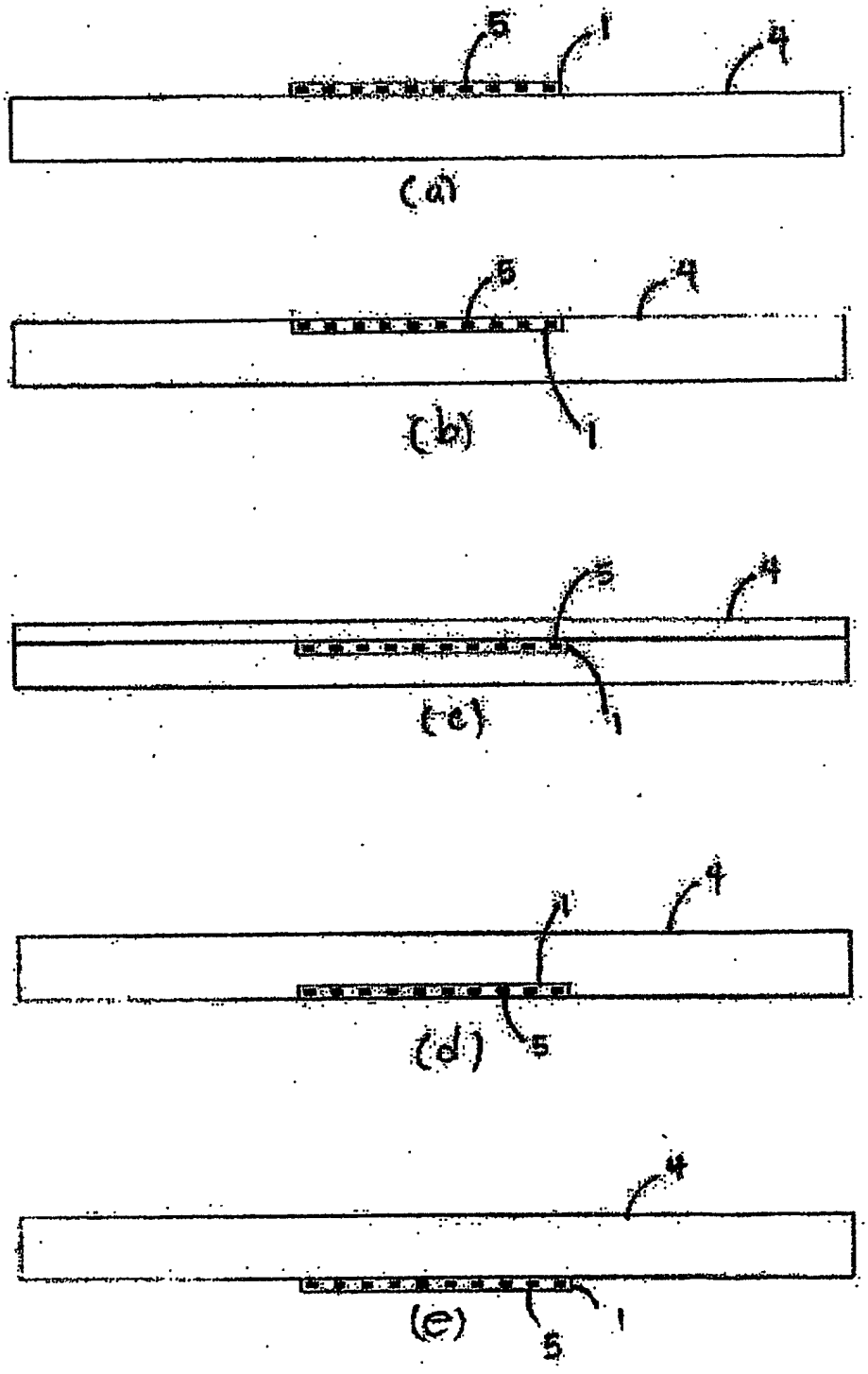

FIGURE 4

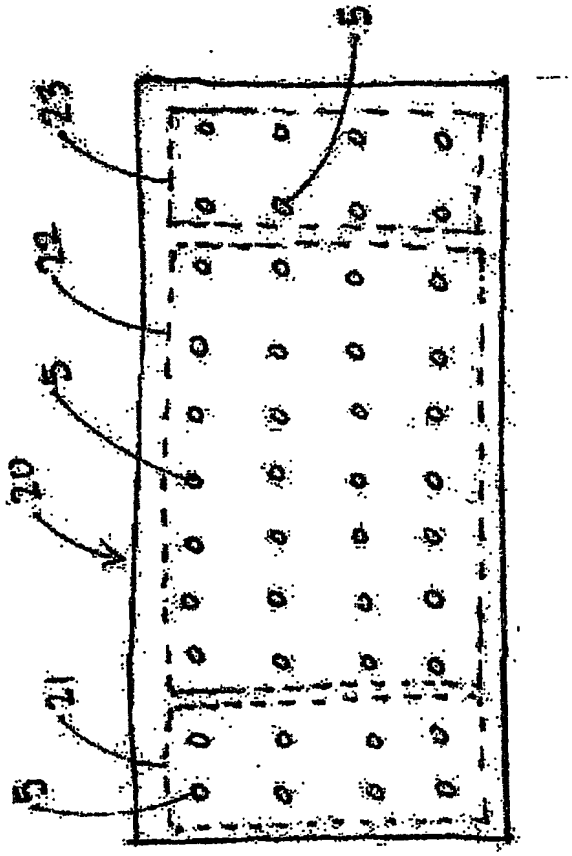

FIGURE 5

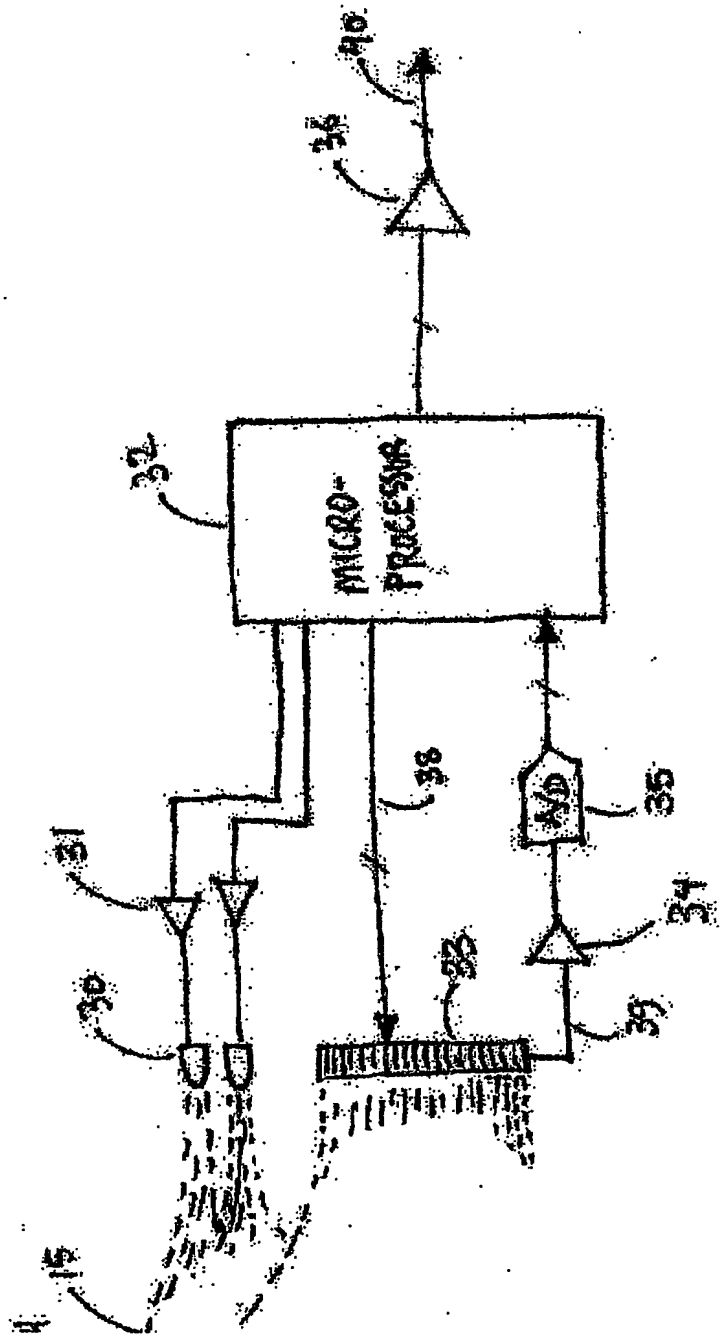

FIGURE 6

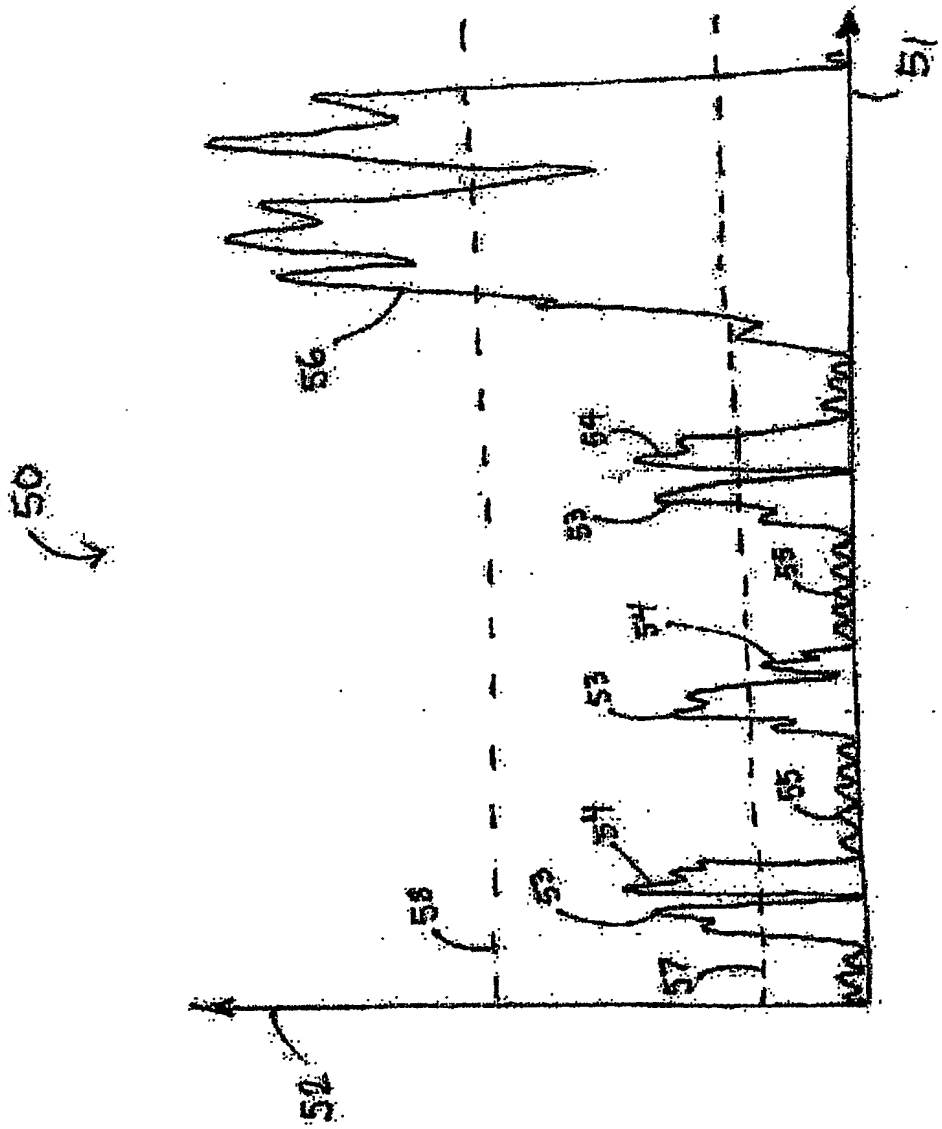

FIGURE 1